



REDUCE AND RECAPTURE CO₂:
**Sustainable Approach for Macro- and
Nano- Scale Carbon in Building Materials**

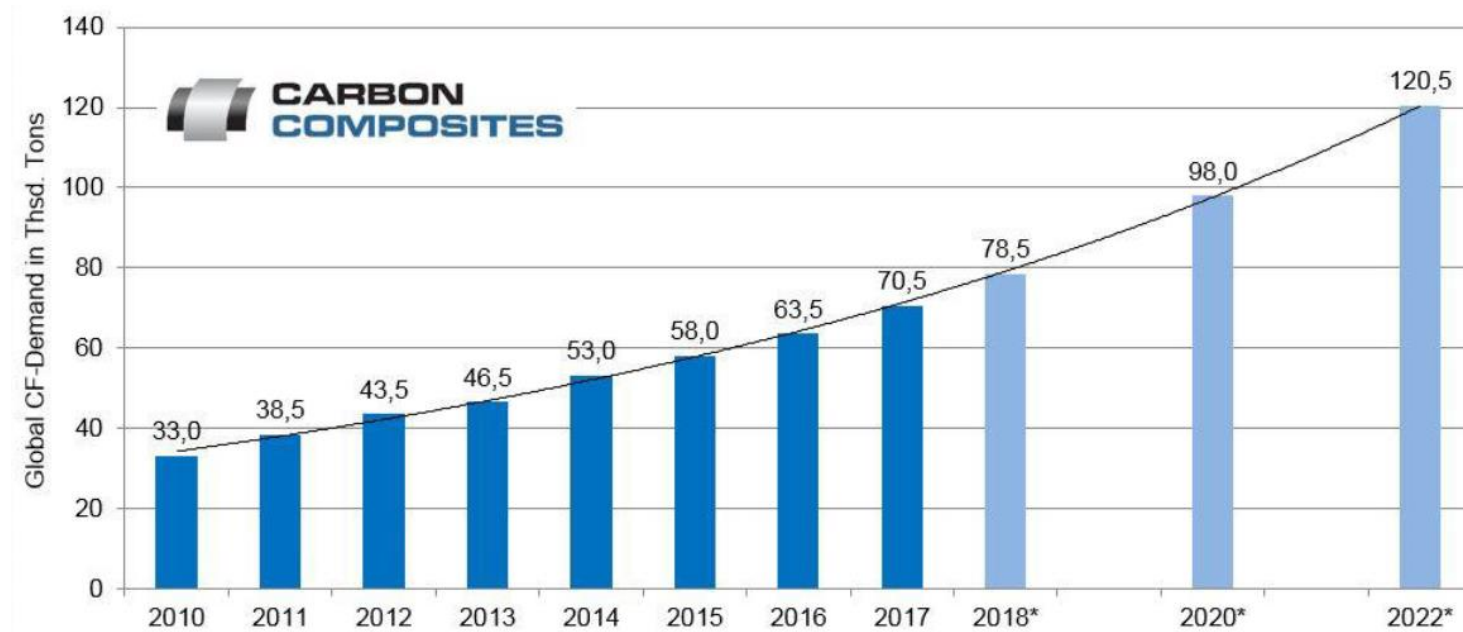
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ARPA-E Workshop

March 25, 2021

THE COMPOSITE MARKET IS ON THE RISE



* According to AVK Composites Market Report 2018 and Freedonia group study 2019



Lighter



Faster



Stronger



Energy intensive process



70 % Yield production



Trims generated waste

THE DARK SIDE OF CARBON FIBER & COMPOSITE PRODUCTION

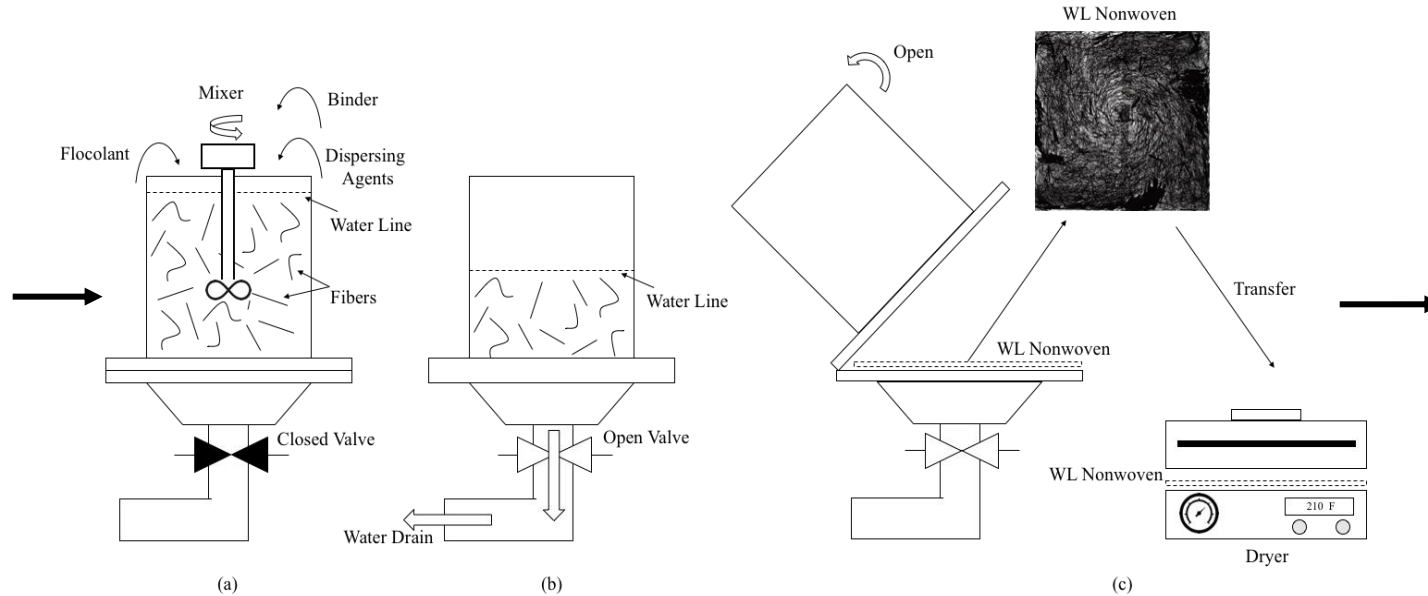
Fibers that end in landfill each year are worth \$1 Billion

WASTE REDUCTION: REPURPOSING OF WASTE INTO NONWOVEN

Defect free wet laid nonwoven preforms made with long chopped fiber “1 inch / 25.4 mm”



Chopped CF at 1”



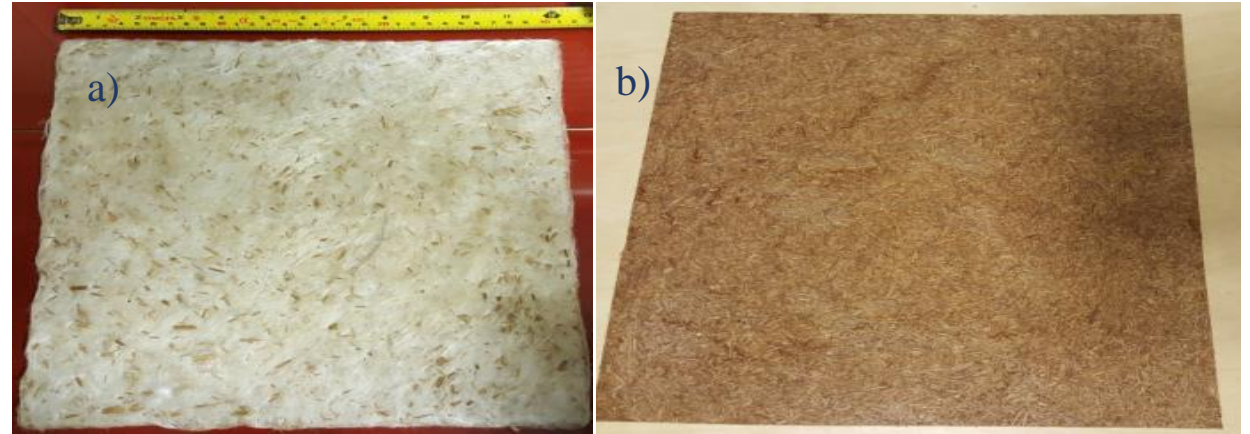
WL Nonwoven CF

- PATENT PENDING PROCESS
- INTERCEPT FIBERS FROM LANDFILL
- CREATE NONWOVEN FABRICS
- HIGH SPEED & LOW-COST PRODUCTION
- ENERGY CONSERVATIVE
- ENVIRONMENTALLY FRIENDLY
- TURNKEY PREFORMS
- \$15 BILLION IN ADDED VALUE PRODUCTS
- POTENTIAL FUNCTIONALITY

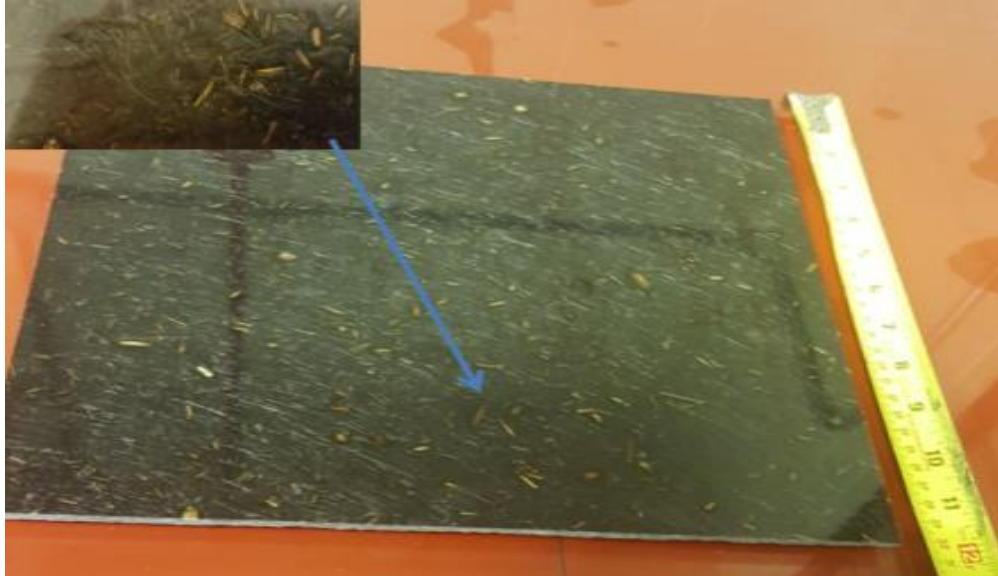
FURTHER REDUCTION IN CARBON FOOTPRINT



Nonwoven bamboo mats with 2% binder



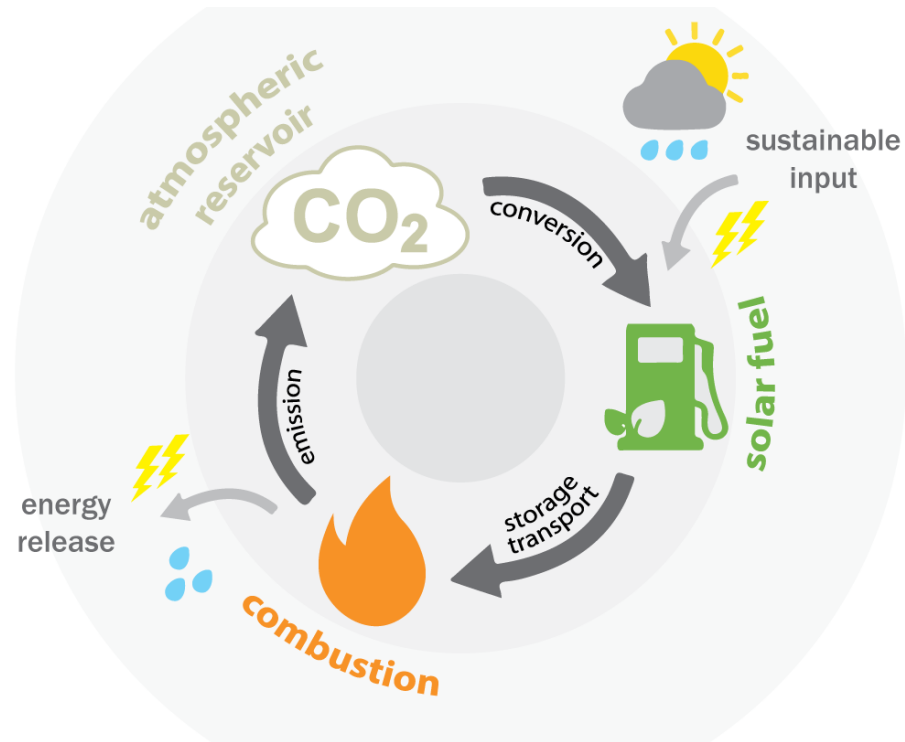
40% in weight bamboo with PP wet laid mat: a) before and b) after compression molding



20% reinforcement with equal quantity of CF and bamboo

- The Wet-laid technology is adopted from the paper making industry
- The usage of natural fiber and mixed reinforcement provides added benefits
- Additional CO2 reduction can be achieved with usage of bio resins for Matrix and carbon negative nano material

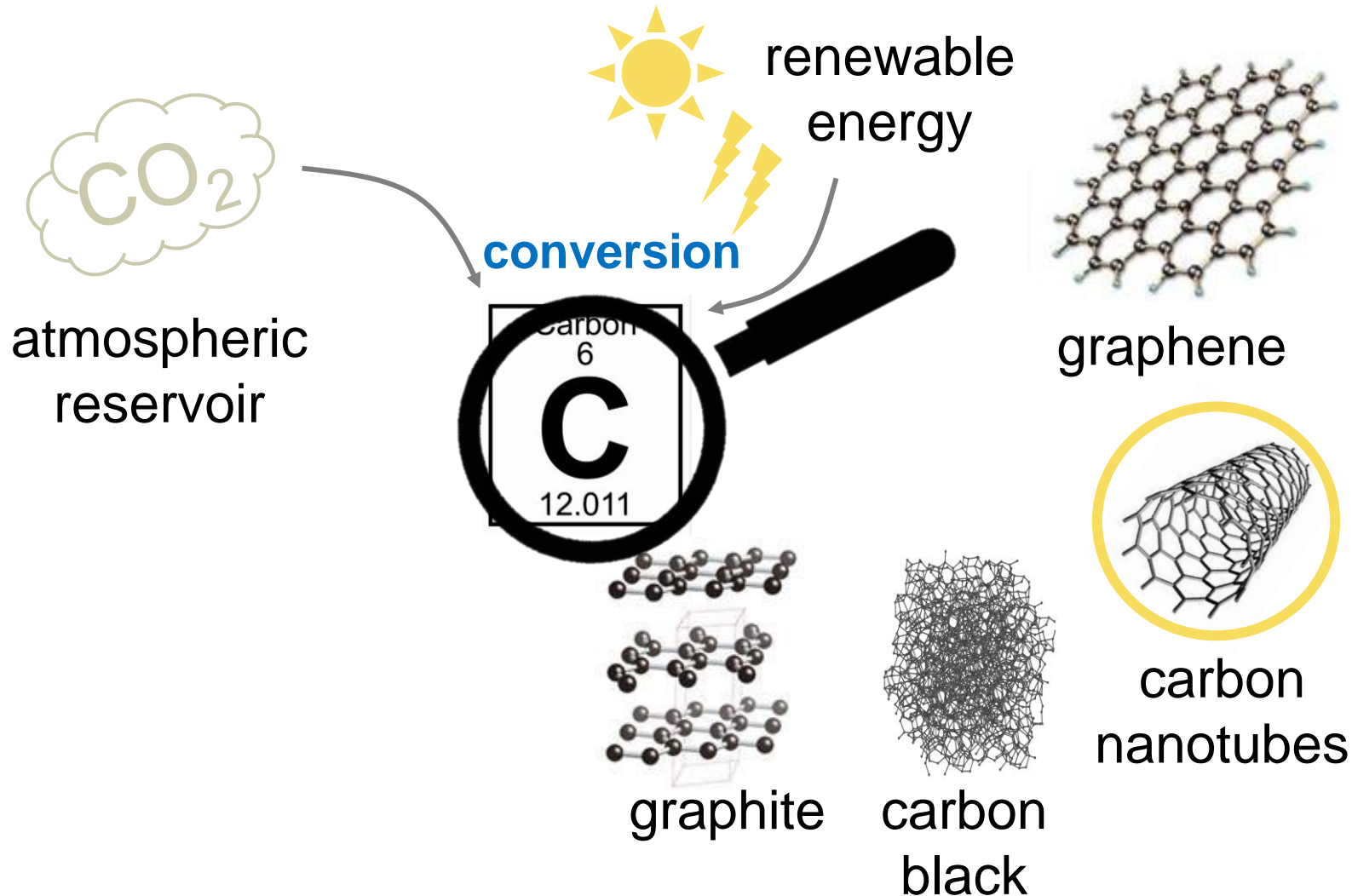
CIRCULAR ECONOMY: NOT ENOUGH



Key Challenges:

- cost of conversion versus perceived economic value of product
- products are used in emissions-generating applications

CO₂→SOLID CARBON STORAGE: BUILDING THE BUILDING BLOCKS

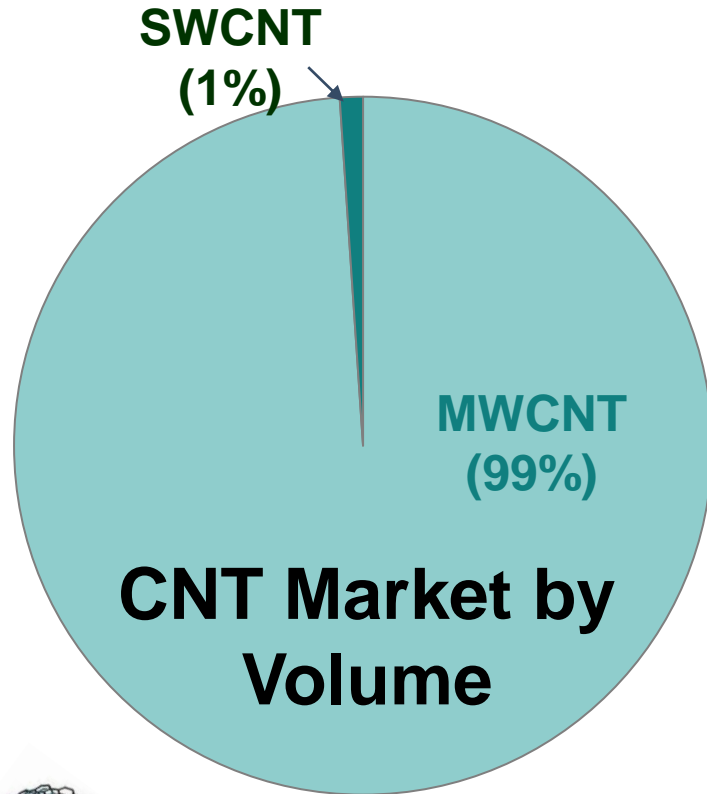


CARBON NANOTUBES

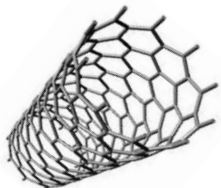
- proven market demand
- high value
- our ability to make them at low cost

CARBON NANOTUBES

Carbon Nanotubes are **non-naturally** earth **occurring** supermaterials with **extraordinary** physical properties.



MWCNT: multi-walled CNT
-\$100+/kg



SWCNT: single-walled CNT
-\$2,000/kg low purity
-\$50,000/kg high purity

Mechanical



200X tensile strength of steel at 1/3 weight

Thermal



7.5X higher than Cu, on par with diamond

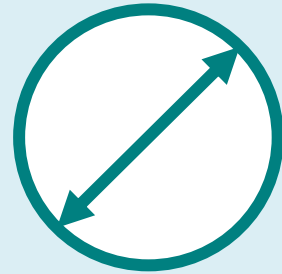
Electrical



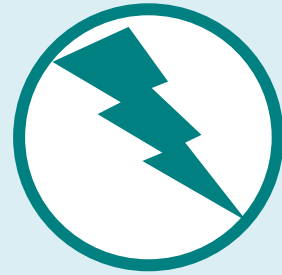
approaching Cu at 5E6 S/cm

Carbon nanotubes have been 2 years away from revolutionizing the world... for 20 years now.

CURRENT CNT BOTTLENECK: MANUFACTURING COST



Scalability barriers



Energy-intensive



Limits applications

NOVEL ELECTROCHEMICAL MANUFACTURING



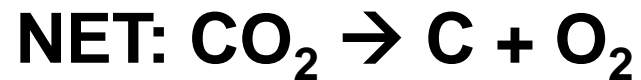
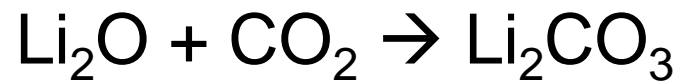
- CO₂ captured/converted from air as chemical feedstock
- Open system facilitates scaling
- Harnesses the **precision** of electrochemistry

Unparalleled Energy Efficiency

No wasted feedstock

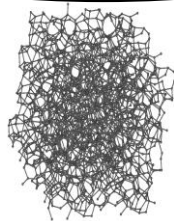
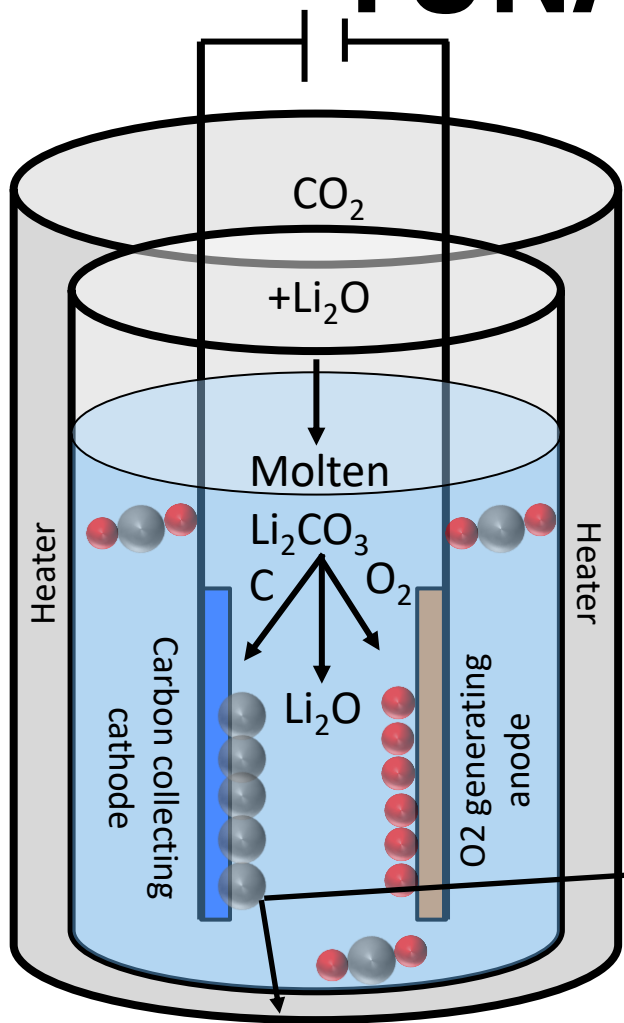
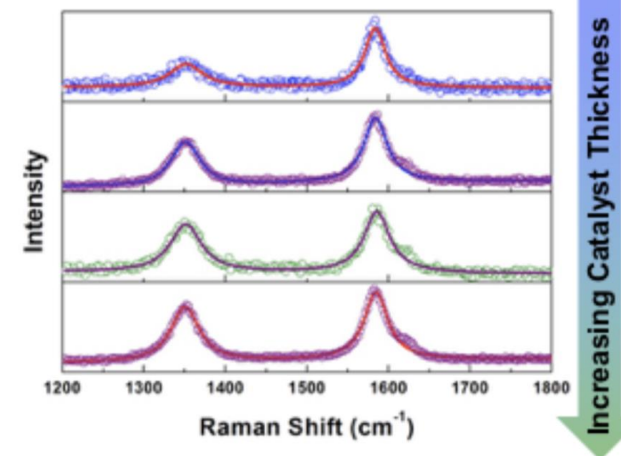
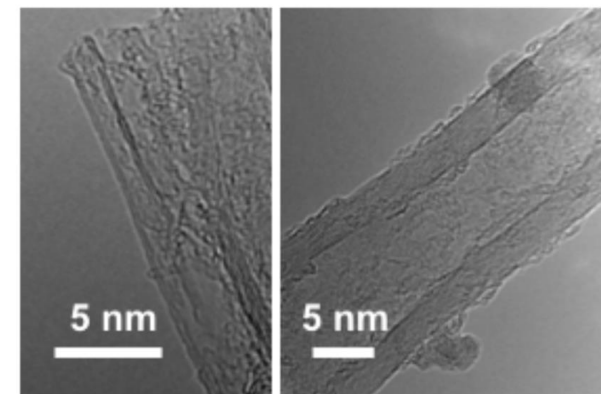
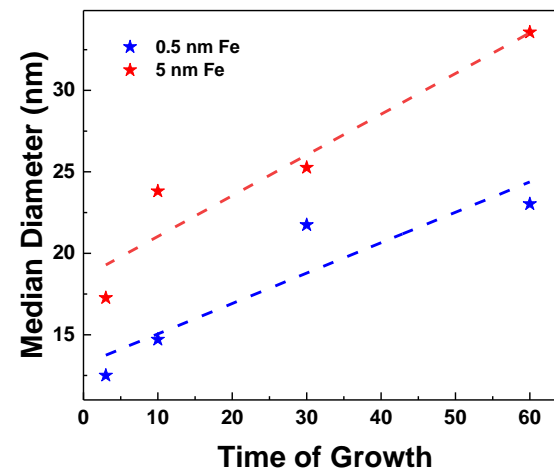
Sustainable

TUNABLE MWCNT PROPERTIES

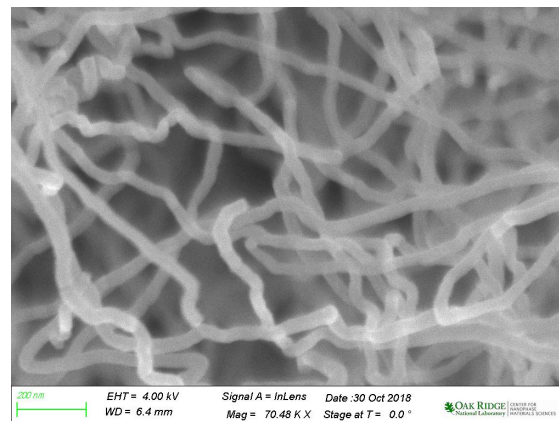
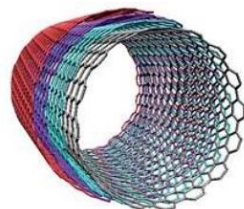


Tunable MWCNT properties based on process parameters – extra knob of control with electrochemistry!

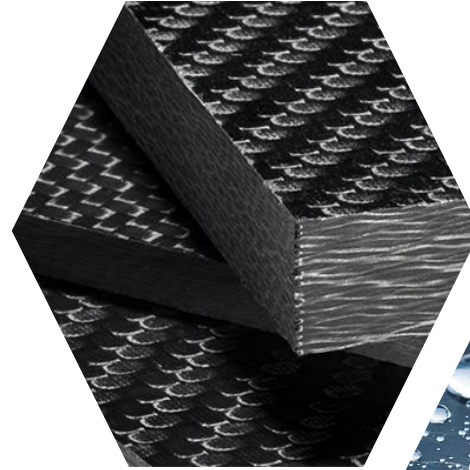
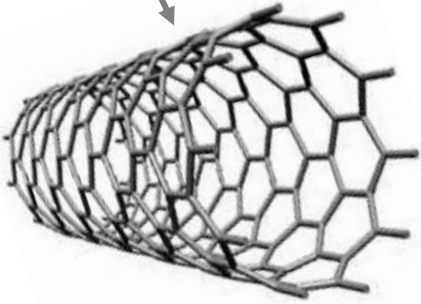
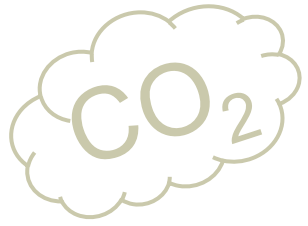
****Electrode architecture to produce high quality CNTs IP protected****



Previously observed carbon particles

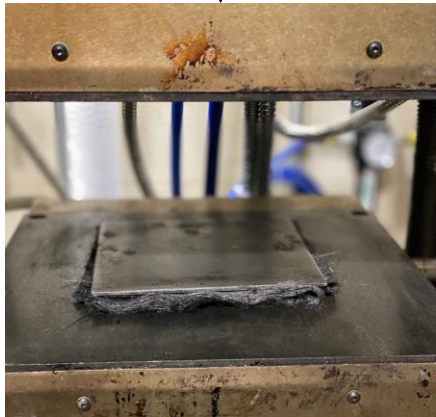


CO₂-DERIVED CNTS IN BUILDINGS



**composites
cement
multi-functional coatings
sensors
smart textiles
so much more!**

SKYNANO + ENDEAVOR: CO₂- NEGATIVE COMPOSITE



50% LDPE

50% SkyNano MWCNTs

Carbon Footprint Calculation:

LDPE: +1.54 kg_{CO2}/kg_{LDPE}**

MWCNTs: -3.66 kg_{CO2}/kg_{MWCNT}

**at 50/50 wt%, total composite
stores over 100% of it's weight in
CO₂**

ongoing aggressive goals to be
more CO₂ negative include:

- biobased polymers
- more CO₂-negative thermoplastics

**source: EPA Plastics report, 2015